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THE SYNTHESIS OF HISTIDINE.

BY

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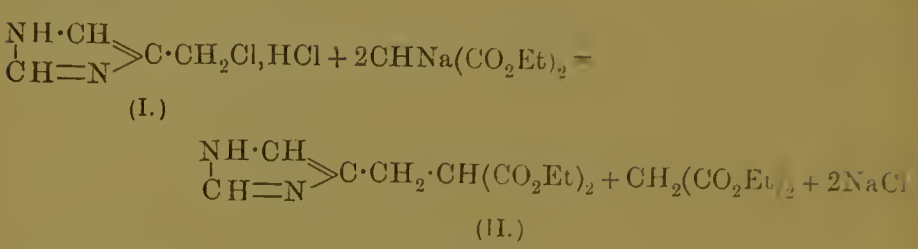
(II) was formed in a yield amounting to 49 per cent. of the theoretical:



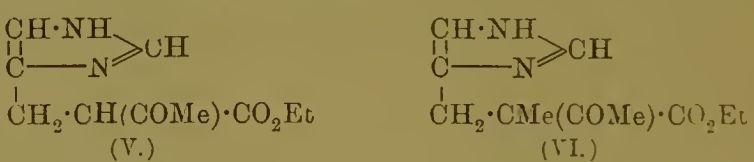
(I.)

(II.)

This ester, on hydrolysis with barium hydroxide, gave the corresponding acid, 4(or 5)-*glyoxalinemethylmalonic acid* (III), together with a certain amount of β-glyoxaline-4(or 5)-propionic acid (IV), produced from the former by the removal of carbon dioxide. 4(or 5)-Glyoxalinemethylmalonic acid is a beautifully crystalline compound, which, on heating, loses carbon dioxide at 180°, and is converted into β-glyoxaline-4(or 5)-propionic acid (IV), a substance which has previously been prepared by Knoop and Windaus (*Beitr. chem. Physiol. Path.*, 1905, 7, 144), both by the degradation of histidine, and synthetically from glyoxylpropionic acid:

(III.) (IV.)

Similar condensation products were obtained by the action of 4(or 5)-chloromethylglyoxaline hydrochloride on ethyl sodioacetoacetate and ethyl sodiomethylacetoacetate, *ethyl* 4(or 5)-*glyoxalinemethylacetoacetate* (V) and *ethyl* 4(or 5)-*glyoxalinemethylmethylacetoacetate* (VI) being formed:

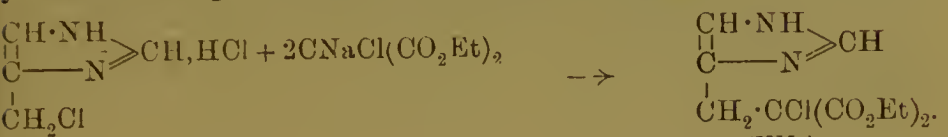


(V.) (VI.)

In view of these results, it seemed of interest to attempt the condensation of this salt with ethyl sodiochloromalonate, since this might lead to a synthesis of histidine, for Conrad (*Annalen*, 1881, **209**, 241) has shown that this ester condenses with benzyl chloride, forming ethyl benzylchloromalonate, although it does not condense with less reactive alkyl chlorides.

On experiment, it was found that 4(or 5)-chloromethylglyoxaline hydrochloride readily condenses with ethyl sodiochloromalonate,

forming *ethyl* 4(or 5)-*glyoxalinemethylchloromalonate* (VII) in a yield amounting to 60 per cent. of the theoretical:



(VII.)

This ester is readily hydrolysed by boiling 20 per cent. hydrochloric acid, losing two molecules of ethyl alcohol and one of carbon dioxide, and thus becoming almost quantitatively converted into r-*α*-*chloro*-*β*-*glyoxaline*-4(or 5)-*propionic acid* (VIII). This acid, when heated with concentrated aqueous ammonia at 110°, yields r-*α*-*amino*-*β*-*glyoxaline*-4(or 5)-*propionic acid* (IX), that is, *r*-histidine, in a yield amounting to 38 per cent. of the theoretical:

(VIII.) (IX.)

The identity of this synthetic *r*-histidine with that obtained by racemising the naturally occurring lævo-variety (Fränkel, *Beitr. chem. Physiol. Path.*, 1906, **8**, 156; Ewins and Pyman, this vol., p. 339) has been established by analyses of the base and two salts, and by the agreements in the melting points of the base and four salts from either source and the respective mixtures.

The synthesis of histidine itself, that is, the naturally occurring lævo-modification, has been completed by the resolution of the racemic variety. When equimolecular amounts of *r*-histidine and *d*-tartaric acid were crystallised from water, there separated first d-*histidine* d-*hydrogen tartrate* (melting point 234° (corr.); $[\alpha]_D$ +13·3°). This salt is sparingly soluble in water, and is obtained in a yield amounting to about 90 per cent. of the theoretical. The hitherto unknown d-*histidine* was regenerated from it, and found to melt at 287—288° (corr.), and to have $[\alpha]_D$ +39·3°. The mother liquors from the *d*-base-*d*-acid then deposited the easily soluble but magnificently crystalline l-*histidine* d-*hydrogen tartrate* (melting point 172—173° (corr.); $[\alpha]_D$ +17·4°) in a yield amounting to nearly 80 per cent. of the theoretical. The *l*-histidine regenerated from this was found to have $[\alpha]_D$ −36·6°, and was therefore further purified by conversion into the sparingly soluble l-*histidine* l-*hydrogen tartrate* (melting point 234° (corr.); $[\alpha]_D$ −12·1°). After regeneration from this salt, *l*-histidine melted at 287—288° (corr.), and had $[\alpha]_D$ −38·1°.

The specific rotatory power is thus substantially in agreement

with that found for natural histidine, $[\alpha]_D$ −39·7° by Kossel and Kutscher (*Zeitsch. physiol. Chem.*, 1899, **28**, 382).

The following scheme shows the steps by which the synthesis of histidine has been effected:

Citric acid.
↓
Acetonedicarboxylic acid.
↓
Di*iso*nitrosoacetone.
↓
Diaminoacetone hydrochloride.
↓
2-Thiol-4(or 5)-aminomethylglyoxaline.
↓
4(or 5)-Hydroxymethylglyoxaline.
↓
4(or 5)-Chloromethylglyoxaline hydrochloride.
↓
Ethyl 4(or 5)-glyoxalinemethylchloromalonate.
↓
r-α-Chloro-β-glyoxaline-4(or 5)-propionic acid.
↓
r-Histidine.
↓
l-Histidine.

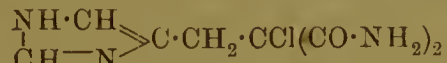
There are a few other points of interest about some of the compounds described. It has already been stated that ethyl 4(or 5)-glyoxalinemethylchloromalonate yields *r*-α-chloro-β-glyoxaline-4(or 5)-propionic acid on hydrolysis with acid, and it was thought that this ester would give the corresponding tartronic acid (X) when boiled with alkali:

(X.)

This, however, was not the case, boiling dilute aqueous sodium hydroxide eliminating one of the nitrogen atoms of the glyoxaline nucleus in the form of ammonia. This remarkable reaction has not yet been further studied, but one other case of a glyoxaline derivative behaving similarly is described in the literature. Thus, Pinner (*Ber.*, 1905, **38**, 2560) found that metapilocarpine—an isomeride of

pilocarpine obtained from the hydrochloride of the latter by prolonged heating at a high temperature—lost half its nitrogen as methylamine when boiled with aqueous potassium hydroxide, nitrogenous acids being produced at the same time. Normally, the glyoxaline ring is quite unaffected by boiling alkalis, except in the case of its quaternary salts, which lose both atoms of nitrogen as the corresponding alkylamines (compare Pinner and Schwarz, *Ber.*, 1902, **35**, 2446).

Ethyl 4(or 5)-glyoxalinemethylchloromalonate gave, with cold alcoholic ammonia, 4(or 5)-*glyoxalinemethylchloromalonamide* (XI), which was isolated in the form of its hydrochloride; strong

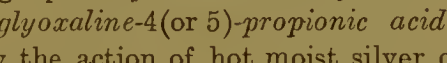


(XI.)

ammonia at 110°, however, gave an uninviting product, which was neglected.

It should be mentioned that the *r*-α-chloro-β-glyoxaline-4(or 5)-propionic acid mentioned above melts at 201° (corr.), that is, 10° higher than the α-chloro-β-glyoxaline-4(or 5)-propionic acid described by Windaus and Vogt (*Beitr. chem. Physiol. Path.*, 1908, **11**, 406). The latter, however, was prepared from *l*-histidine, and is doubtless the corresponding optically active variety.

r-α-*Hydroxy-β-glyoxaline*-4(or 5)-*propionic acid* (XII) has also been prepared by the action of hot moist silver oxide on *r*-α-chloro-

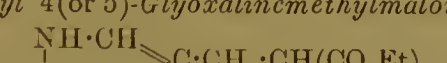


(XII.)

β-glyoxaline-4(or 5)-propionic acid. It melts at 222° (corr.), thus differing from the "oxydeaminohistidine," that is, α-hydroxy-β-glyoxaline-4(or 5)-propionic acid, melting at 204°, prepared by Fränkel (*Monatsh.*, 1903, **24**, 229) by the action of silver nitrite on *l*-histidine. Here again the difference lies, no doubt, in the optical activity of the acid obtained from the natural product. Both acids crystallise with one molecule of water of crystallisation.

Experimental.

Ethyl 4(or 5)-*Glyoxalinemethylmalonate*,



Twenty grams of 4(or 5)-chloromethylglyoxaline hydrochloride were brought into reaction with two molecular proportions of ethyl sodiomalonate, and the product worked up in the same way as that from ethyl sodiochloromalonate (p. 1392); the yield was 21 grams

of *ethyl* 4(or 5)-*glyoxalinemethylmalonate hydrogen oxalate*, that is, 49 per cent. of the theoretical.

Ethyl 4(or 5)-*glyoxalinemethylmalonate hydrogen oxalate* crystallises from water in large, hard, clear, nearly rectangular, oblong plates, which melt at 155—158° (corr.). It is anhydrous, sparingly soluble in cold, but readily so in hot, water:

0·1488 gave 0·2564 CO_2 and 0·0727 H_2O. C = 47·0; H = 5·5.

0·1413 „ 10·6 c.c. N_2 at 19° and 778 mm. N = 9·0.

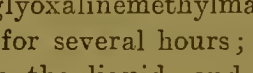
$C_{11}H_{16}O_4N_2,C_2H_2O_4$ requires C = 47·2; H = 5·5; N = 8·5 per cent.

The base was regenerated from the oxalate by means of sodium carbonate and ether; after distillation of the solvent, it remained as a yellow oil, which became very viscid when cold, but readily poured when warm. It showed no signs of crystallisation after long keeping. It is sparingly soluble in water, but readily so in alcohol or ether.

The *hydrochloride* occurs as a deliquescent mass of needles, melting indefinitely at 50—70°, and readily soluble in water, alcohol, acetone, or ethyl acetate.

The *hydriodide* is a crystalline salt of similar properties.

4(or 5)-*Glyoxalinemethylmalonic Acid*,



Ethyl 4(or 5)-glyoxalinemethylmalonate was boiled with an excess of baryta water for several hours; a stream of carbon dioxide was then led through the liquid, and the barium carbonate removed by filtration. The clear filtrate, containing the barium salts of 4(or 5)-glyoxalinemethylmalonic acid and β-glyoxaline-4(or 5)-propionic acid, was then made up to a known volume, and the barium in an aliquot portion determined.

The liquor was then treated with a quantity of oxalic acid exactly sufficient to remove the barium, filtered from barium oxalate, and concentrated to low bulk, when 4(or 5)-glyoxalinemethylmalonic acid crystallised out on cooling; the mother liquor contained β-glyoxaline-4(or 5)-propionic acid.

4(or 5)-*Glyoxalinemethylmalonic acid* crystallises from water in beautiful, clear, hexagonal plates. It is easily soluble in hot water, but sparingly so in cold water or alcohol:

0·1512 gave 0·2530 CO_2 and 0·0596 H_2O. C = 45·6; H = 4·4.

$C_7H_8O_4N_2$ requires C = 45·6; H = 4·4 per cent.

When heated, this malonic acid melts and effervesces at 180° (corr.), losing carbon dioxide; it resolidifies while still hot, and does not then melt until 207° (corr.), β-glyoxaline-4(or 5)-propionic acid.

$C_3H_3N_2\cdot CH_2\cdot CH_2\cdot CO_2H$, being formed. A quantity of the latter acid was prepared in this manner, and after recrystallisation from water melted at 209—210° (corr.). (Found, C = 51·1; H = 6·0. Calc., C = 51·4; H = 5·8 per cent.) Knoop and Windaus, who have previously prepared this acid in other ways (*Beitr. chem. Physiol. Path.*, 1905, 7, 144), give m. p. 208—209°.

Ethyl 4(or 5)-*Glyoxalinemethylacetoacetate*,
$C_3H_3N_2\cdot CH_2\cdot CH(COMe)\cdot CO_2Et$.

This compound was prepared by condensing 4(or 5)-chloromethylglyoxaline hydrochloride (1 mol.) with ethyl sodioacetoacetate (2 mols.).

The *hydrogen oxalate* crystallises from water in rosettes of thin, clear plates, which melt and decompose at 145—146° (corr.). It is anhydrous, fairly readily soluble in cold water, and easily so in hot:

0·1535 gave 0·2704 CO_2 and 0·0751 H_2O. C = 48·0; H = 5·5.
0·1148 „ 9·3 c.c. N_2 at 17° and 754 mm. N = 9·5.
$C_{10}H_{14}O_3N_2,C_2H_2O_4$ requires C = 48·0; H = 5·3; N = 9·3 per cent.

Ethyl 4(or 5)-*Glyoxalinemethylmethylacetoacetate*,
$C_3H_3N_2\cdot CH_2\cdot CMe(COMe)\cdot CO_2Et$.

This compound was prepared by condensing 4(or 5)-chloromethylglyoxaline hydrochloride (1 mol.) with ethyl sodiomethylacetoacetate (2 mols.).

The *hydrogen oxalate* crystallises from water in clusters of beautiful, clear, glistening plates, which melt and decompose at 155—156° (corr.). It is anhydrous, fairly readily soluble in cold water, and easily so in hot:

0·1525 gave 0·2874 CO_2 and 0·0823 H_2O. C = 51·4; H = 6·1.
0·1300 „ 10·2 c.c. N_2 at 18° and 762 mm. N = 9·2.
$(C_{11}H_{16}O_3N_2)_4,(C_2H_2O_4)_3$ requires C = 51·4; H = 6·1; N = 9·6 per cent.

On regenerating the base, dissolving it in absolute alcoholic hydrogen chloride, and evaporating nearly to dryness in an evacuated desiccator, a crystalline *hydrochloride* separated in deliquescent needles, which were very easily soluble in water, alcohol, acetone, or ethyl acetate.

Ethyl 4(or 5)-*Glyoxalinemethylchloromalonate*,
$\begin{matrix}NH\cdot CH\\ \|\\ CH{=}N\end{matrix}\!\!>C\cdot CH_2\cdot CCl(CO_2Et)_2$.

To 2·2 grams of sodium, dissolved in 200 c.c. of absolute alcohol, 18 grams of ethyl chloromalonate were added, followed by a solution

of 30·6 grams of 4(or 5)-chloromethylglyoxaline hydrochloride in 150 c.c. of absolute alcohol, the liquid being kept cold during both additions. The mixture was then boiled for one and a-half hours under a reflux condenser, filtered from sodium chloride, and the solvent removed by distillation. The resulting oil was mixed with dilute hydrochloric acid, and extracted with ether to remove the non-basic esters; the liquor was then rendered alkaline with sodium carbonate, and completely extracted with ether. The residue, after evaporation of the solvent, consisting of a clear, brown oil, was dissolved in a solution of 25 grams of oxalic acid in 550 c.c. of boiling water, and decolorised with animal charcoal. On cooling, 39 grams of pure *ethyl* 4(or 5)-*glyoxalinemethyl chloromalonate hydrogen oxalate* separated, and further small quantities (about 3 grams) were obtained from the mother liquors, the yield thus amounting to 60 per cent. of the theoretical.

Ethyl 4(or 5)-*glyoxalinemethylchloromalonate hydrogen oxalate* crystallises from water in shimmering leaflets, which melt and decompose at 176° (corr.). This salt is sparingly soluble in cold water, but readily so in hot. It is anhydrous:

0·1517 gave 0·2442 CO_2 and 0·0647 H_2O. C = 43·9; H = 4·8.
0·1507 „ 0·2415 CO_2 „ 0·0635 H_2O. C = 43·7; H = 4·7.
0·2315 „ 0·0991 AgCl. Cl = 10·6.

$(C_{11}H_{15}O_4N_2Cl)_4,(C_2H_2O_4)_3$ requires C = 43·8; H = 4·8; Cl = 10·4 per cent.

The *hydrochloride* crystallises from acetone in beautiful, large, glistening, diamond-shaped plates, which melt at 148—149° (corr.). It is anhydrous, readily soluble in water or alcohol, fairly readily so in hot acetone, and sparingly so in cold acetone:

0·1556 gave 0·2423 CO_2 and 0·0739 H_2O. C = 42·5; H = 5·3.
$C_{11}H_{15}O_4N_2Cl,HCl$ requires C = 42·4; H = 5·2 per cent.

Aqueous solutions of the hydrochloride give a sparingly soluble precipitate with picric acid or Meyer's solution, and give a deep red coloration with sodium diazobenzene-*p*-sulphonate in alkaline solution. The free base was regenerated by shaking the salts with sodium carbonate and ether; it formed a viscid oil which did not crystallise, and is easily soluble in alcohol, ether, or chloroform, but very sparingly so in water.

Ethyl 4(or 5)-glyoxalinemethylchloromalonate yields, on hydrolysis with 20 per cent. hydrochloric acid, *r*-α-chloro-β-glyoxaline-4(or 5)-propionic acid. When hydrolysed by boiling with dilute aqueous sodium hydroxide, however, it loses half its nitrogen as ammonia. This was determined quantitatively by absorption in dilute sulphuric acid in the usual way.

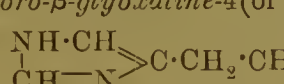
0·2532 (oxalate) gave NH_3 requiring 7·4 c.c. $N/10$-H_2SO_4; N = 4·1.

0·5008 (oxalate) gave NH_3 requiring 15·2 c.c. $N/10$-H_2SO_4; N = 4·3.

$(C_{11}H_{15}O_4N_2Cl)_4,(C_2H_2O_4)_3$ requires total N = 8·2 per cent.

With cold ammonia, it yields 4(or 5)-glyoxalinemethylchloromalonamide, but with strong ammonia at 110° only dark brown, uninviting products are obtained.

r-α-Chloro-β-glyoxaline-4(or 5)-*propionic Acid*,



Ten grams of ethyl 4(or 5)-glyoxalinemethylchloromalonate hydrochloride were boiled with 100 c.c. of 20 per cent. hydrochloric acid for forty-five minutes. The liquor was evaporated to dryness under diminished pressure, moistened with water, and again evaporated to dryness. The resulting colourless varnish was dissolved in 300 c.c. of cold water, digested cold with the silver carbonate from 8 grams of silver nitrate, filtered from silver chloride, and treated with hydrogen sulphide. After the removal of silver sulphide, the filtrate was evaporated to low bulk under diminished pressure, and allowed to crystallise, when 5·1 grams of pure *r*-α-chloro-β-glyoxaline-4(or 5)-propionic acid were obtained; this yield represents 91 per cent. of the theoretical.

r-α-*Chloro-β-glyoxaline*-4(or 5)-*propionic acid* crystallises from water in white, star-like clusters of prismatic needles. It is anhydrous, and melts and decomposes at 201° (corr.), but the melting point varies considerably with the rate of heating, and may be found anywhere between 198° and 204° (corr.). It is sparingly soluble in cold water, alcohol, or acetone, but readily so in hot water:

0·1547 gave 0·2334 CO_2 and 0·0571 H_2O. C = 41·1; H = 4·1.

0·1604 „ 0·1319 AgCl. Cl = 20·3.

$C_6H_7O_2N_2Cl$ requires C = 41·3; H = 4·1; Cl = 20·3 per cent.

The α-chloro-β-glyoxaline-4(or 5)-propionic acid previously described by Windaus and Vogt (*Beitr. chem. Physiol. Path.*, 1908, **11**, 406) is stated to melt at 191°; it is doubtlessly the optically active variety corresponding with *l*-histidine, from which it was prepared.

Synthesis of r-*Histidine.*

$$\begin{matrix} NH\cdot CH \\ | \\ CH{=}N \end{matrix}\!\!>\!C\cdot CH_2\cdot CH(NH_2)\cdot CO_2H.$$

Two and a-half grams of *r*-*α*-chloro-*β*-glyoxaline-4(or 5)-propionic acid were dissolved in 50 c.c. of concentrated ammonia (D 0·880), and heated at 110° under pressure for three hours. The liquor was then evaporated to dryness under diminished pressure, and the residue dissolved in a little water and again evaporated. The residue was dissolved in a few c.c. of water, and set aside, when 1·1 grams of r-*histidine monohydrochloride* separated in stout needles, melting at 110—115°; after recrystallisation from water, this salt melted at 117—119° (corr.), after sintering earlier.

A larger quantity of synthetic *r*-histidine was then prepared as follows: Twenty grams of ethyl 4(or 5)-glyoxalinemethylchloromalonate were converted into *r*-*α*-chloro-*β*-glyoxaline-4(or 5)-propionic acid hydrochloride by boiling for half an hour with 200 c.c. of 20 per cent. hydrochloric acid, and evaporating the liquor to dryness under diminished pressure.

The resulting colourless varnish was again twice dissolved in water, and evaporated to dryness to remove free hydrochloric acid. It was then dissolved in 240 c.c. of concentrated ammonia (D 0·880), and heated under pressure to 110° for three hours. The liquor was then evaporated to dryness under diminished pressure to remove the excess of ammonia, and the residue dissolved in about 40 c.c. of water. On keeping overnight in an evacuated desiccator over sulphuric acid, the liquor was covered with a crust of ammonium chloride. After the removal of this by filtration, the filtrate began to deposit crystals, and on keeping became semi-solid. The crystals were collected after about half an hour, and, after recrystallisation from water, melted at 117—119° (corr.); they were r-*histidine monohydrochloride*. On concentrating the mother liquors, further crops of this salt and ammonium chloride were obtained; these were separated by fractional crystallisation from water, and a total quantity of 6·3 grams of *r*-histidine monohydrochloride was isolated in a pure state; this yield is 38 per cent. of the theoretical.

Synthetic r-*Histidine.*

r-*Histidine monohydrochloride* forms clusters of stout needles (from water), which sinter at 112°, and melt at 117—119° (corr.). It contains two molecules of water of crystallisation, of which only about 1½ molecules are lost at 100°. This salt is easily soluble in water, but sparingly so in alcohol:

0·1556 * lost 0·0196 at 100°. $H_2O = 12·6$.
0·1530 * gave 0·1781 CO_2 and 0·0857 H_2O. $C = 31·7$; $H = 6·3$.
0·1009 * „ 16·0 c.c. N_2 at 16° and 765 mm. $N = 18·9$.
0·1634 * „ 0·1010 AgCl. $Cl = 15·3$.

$C_6H_9O_2N_3,HCl,2H_2O$ requires $C = 31·6$; $H = 6·2$; $N = 18·5$; $Cl = 15·6$; and $1\frac{1}{2}H_2O = 11·9$ per cent.

When this salt was dissolved in a little water, and a large excess of absolute alcoholic hydrogen chloride added, the dihydrochloride was precipitated in an amorphous form, but quickly became a crystalline powder on stirring. This salt began to sinter at 230°, and decomposed at 235—236° (corr.):

0·1505 gave 0·1750 CO_2 and 0·0638 H_2O. $C = 31·7$; $H = 4·8$.
0·1088 „ 0·1359 AgCl. $Cl = 30·9$.

$C_6H_9O_2N_3,2HCl$ requires $C = 31·6$; $H = 4·9$; $Cl = 31·1$ per cent.

On dissolving the dihydrochloride in a little water and adding alcohol, the sesquihydrochloride separated on keeping in clusters of prismatic needles, which melted at 168—170° (corr.).

These three hydrochlorides of synthetic *r*-histidine were compared with the corresponding salts of *r*-histidine prepared by racemising *l*-histidine, and found to be identical with them; in each case the corresponding salt and the mixture of the synthetic and racemised salt melted simultaneously.

The melting point of racemised histidine dihydrochloride, given by Fränkel (*loc. cit.*) as 220°, and by Ewins and Pyman (*loc. cit.*) as 225° (corr.), is too low; a re-determination has shown that it should be 235—236° (corr.).

r-*Histidine* was prepared from the synthetic monohydrochloride by digesting it with silver oxide, and filtering to remove silver chloride, removing the excess of silver with hydrogen sulphide, and evaporating to low bulk under diminished pressure. After recrystallisation from water, it formed well defined quadrilateral plates, which decomposed at 283° (corr.) simultaneously with a specimen prepared by racemising *l*-histidine, and a mixture of the two in the same bath. It is anhydrous, and is sparingly soluble in cold water, easily so in hot water, but almost insoluble in absolute alcohol and the other usual organic solvents:

0·1514 gave 0·2551 CO_2 and 0·0806 H_2O. $C = 46·0$; $H = 6·0$.
0·0859 „ 20·0 c.c. N_2 at 22° and 763 mm. $N = 27·0$.

$C_6H_9O_2N_3$ requires $C = 46·4$; $H = 5·9$; $N = 27·1$ per cent.

r-Histidine dipicrate was also prepared from the synthetic monohydrochloride, and proved to be identical with the salt described by Ewins and Pyman (*loc. cit.*). It should be mentioned that this

* Air-dried.

salt—from either source—when dried in the air for only a short time, melts at about 103° (corr.), and then, after drying at 100°, sometimes melts between 140° and 150°, although it does not decompose until 190°. When thoroughly air-dried, however, and then dried at 100°, it sinters at about 183°, and melts and decomposes at 190° (corr.).

Resolution of r-*Histidine.*

With the object of finding a suitable method for the resolution of synthetic *r*-histidine, some salts of natural histidine with optically active acids were first prepared.

The histidine used for this purpose was prepared from hæmoglobin, and the free base was obtained from its hydrochloride by means of silver carbonate, a method due to Fränkel (*Monatsh.*, 1903, **24**, 229). The base decomposed at 287° (corr.), a temperature considerably higher than that given by Fränkel, namely 253°, and it was therefore analysed. (Found, C = 46·0; H = 6·1. Calc., C = 46·4; H = 5·9 per cent.)

Its specific rotatory power was then determined in a 1-dcm. tube:

0·2, in 10 c.c. of water at 26°, gave α_D −0·74°, whence $[\alpha]_D$ −37·0°.

1·015, in 25 c.c. of water at 28°, gave α_D −1·49°, whence $[\alpha]_D$ −36·7°.

Kossel and Kutscher (*Zeitsch. physiol. Chem.*, 1899, **28**, 382) give $[\alpha]_D$ −39·7°.

It was found that the *d*-camphorsulphonate and neutral *d*-tartrate of this base were very readily soluble in water, and crystallised from this solvent with difficulty.

l-*Histidine* d-*hydrogen tartrate*, however, crystallises from water in beautiful, large, clear, colourless, well defined prisms, often separating in triangular plates with bevelled edges. It is anhydrous, and easily soluble in water. This salt decomposes at 172—173° (corr.):

0·1535 gave 0·2188 CO_2 and 0·0718 H_2O. C = 38·9; H = 5·2.

$C_6H_9O_2N_3,C_4H_6O_6$ requires C = 39·3; H = 5·0 per cent.

The specific rotatory power of this salt was determined in a 2-dcm. tube; it appears to diminish with increasing concentration:

0·1616, in 15 c.c. of water at 24°, gave α_D +0·37°, whence $[\alpha]_D$ +17·2.

0·5587, in 15 c.c. of water at 24°, gave α_D +1·26°, whence $[\alpha]_D$ +16·9.

0·7474, in 15 c.c. of water at 25°, gave α_D +1·62°, whence $[\alpha]_D$ +16·3.

The base was then regenerated from the pure salt as follows, the

method adopted being substantially that used by Fränkel (*loc. cit.*) for the isolation of histidine from the hydrolytic products of hæmoglobin. The tartrate was dissolved in a large volume of water, and precipitated by mercuric chloride and sodium carbonate; the precipitate was thoroughly washed with water, dissolved in dilute hydrochloric acid, and treated with hydrogen sulphide. After the removal of mercuric sulphide, the liquor was evaporated to dryness under diminished pressure, moistened with water, and again evaporated to dryness to remove free hydrochloric acid. The residue was then dissolved in water, shaken with silver carbonate, filtered from silver chloride, treated with hydrogen sulphide, filtered from silver sulphide, and evaporated to low bulk, when the base crystallised out.

Its specific rotatory power was determined in a 2-dcm. tube:

0·504, in 15 c.c. of water at 22°, gave α_D −2·53°, whence $[\alpha]_D$ −37·7°.

In view of the satisfactory crystalline nature of *l*-histidine *d*-hydrogen tartrate, it was determined to attempt the resolution of synthetic *r*-histidine by fractional crystallisation of the *d*-hydrogen tartrate, and 0·73 gram of synthetic *r*-histidine and 0·7 gram of *d*-tartaric acid were accordingly dissolved in a little water and kept. After a short time there crystallised out 0·6 gram of a sparingly soluble salt, melting at 234° (corr.), which is subsequently shown to be *d*-histidine *d*-hydrogen tartrate, and the mother liquors from this salt, after spontaneous evaporation in a desiccator over sulphuric acid, deposited about 0·2 gram of clear prisms, melting at 172—173° (corr.), which were identical with *l*-histidine *d*-hydrogen tartrate. The resolution of a larger quantity of synthetic histidine was then carried out as follows: 3·5 grams of synthetic *r*-histidine and 3·4 grams of *d*-tartaric acid were dissolved in water, and evaporated to a volume of about 20 c.c., when crystals began to separate from the hot solution. The evaporation was then continued to a volume of about 15 c.c., and the liquor set aside. Clusters of prisms, melting at 234° (corr.), and amounting to 2·9 grams, were then collected, and on concentrating the mother liquor and keeping, a further 0·28 gram of the same salt were obtained.

On recrystallising this salt from water, 3·05 grams of *d*-histidine *d*-hydrogen tartrate were obtained.

d-*Histidine* d-*hydrogen tartrate* crystallises from water in clusters of small prisms, which decompose at 234° (corr.). It dissolves in 25 to 30 parts of cold water, and more readily in hot water. It is anhydrous:

0·1561 gave 0·2237 CO_2 and 0·0694 H_2O. C = 39·1; H = 5·0.
$C_6H_9O_2N_3,C_4H_6O_6$ requires C = 39·3; H = 5·0 per cent.

Its specific rotatory power was determined in a 2-dcm. tube:

0·9220, in 25 c.c. of water at 28°, gave α_D +0·98°, whence $[\alpha]_D$ +13·3°.

This salt was converted into the free base by the method given above.

d-*Histidine* crystallises from water in beautiful, colourless, monoclinic plates, forming elongated hexagons. It decomposes at 287—288° (corr.), and is anhydrous. It is sparingly soluble in cold water, easily so in hot water, and almost insoluble in absolute alcohol and the other usual organic solvents:

0·1532 gave 0·2608 CO_2 and 0·0807 H_2O. C = 46·4; H = 5·9.
$C_6H_9O_2N_3$ requires C = 46·4; H = 5·9 per cent.

Its specific rotatory power was determined in a 2-dcm. tube:

0·401, in 15 c.c. of water at 23°, gave α_D +2·10°, whence $[\alpha]_D$ +39·3°.

The mother liquor from the *d*-histidine *d*-hydrogen tartrate was then somewhat concentrated, and inoculated with a trace of the *l*-histidine *d*-hydrogen tartrate obtained in the preliminary experiment mentioned above, when there crystallised 1·65 grams of this salt in clear prisms, decomposing at 172—173° (corr.), and on concentrating the mother liquors, a further 1·05 grams, equally pure. The ultimate mother liquors which continued to deposit crystalline material were neglected.

The melting point of the *l*-base-*d*-acid was unchanged by recrystallising the salt, or mixing it with natural *l*-histidine *d*-hydrogen tartrate. The salt was, however, recrystallised, and its specific rotatory power was determined in a 2-dcm. tube, and found to be in agreement with that of the natural salt at corresponding concentrations:

0·8625, in 25 c.c. of water at 27°, gave α_D +1·20°, whence $[\alpha]_D$ +17·4°.

0·8200, in 15 c.c. of water at 23°, gave α_D +1·76°, whence $[\alpha]_D$ +16·1°.

The recrystallised salt and its mother liquor (= 2·7 grams of *l*-base-*d*-acid) were then recombined, and the base regenerated.

The specific rotatory power of the latter was determined in a 2-dcm. tube:

0·4143, in 15 c.c. of water at 26°, gave α_D −2·02°, whence $[\alpha]_D$ −36·6°.

This figure being somewhat low, the whole of the regenerated

base (1·1 grams) was converted into the *l*-hydrogen tartrate, and crystallised from water.

l-Histidine l-hydrogen tartrate crystallises from water in clusters of prisms, which decompose at 234° (corr.). It is sparingly soluble in cold water. A specimen of this salt prepared from natural histidine had the same melting point and specific rotatory power. The latter was determined in a 2-dcm. tube:

0·6792 (synthetic), in 15 c.c. of water at 22°, gave α_D −1·10°, whence $[\alpha]_D$ −12·1°.

0·6796 (natural), in 15 c.c. of water at 25°, gave α_D −1·10°, whence $[\alpha]_D$ −12·1°.

The synthetic salt was then converted into the free base in the usual way.

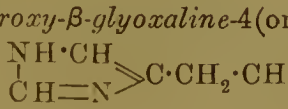
Synthetic *l*-histidine crystallised from water in monoclinic plates, forming elongated hexagons, which decomposed at 287—288° (corr.). Its decomposition point is not depressed by admixture of the base with natural *l*-histidine, but this is of little importance, since it is only depressed about 2° by admixture with *r*-histidine. It is sparingly soluble in cold water, easily so in hot water, and almost insoluble in absolute alcohol and the other usual organic solvents:

0·1402 gave 0·2358 CO_2 and 0·0756 H_2O. C = 45·9; H = 6·0.
$C_6H_9O_2N_3$ requires C = 46·4; H = 5·9 per cent.

Its specific rotatory power was determined in a 2-dcm. tube:

0·3447, in 15 c.c. of water at 26°, gave α_D −1·75°, whence $[\alpha]_D$ −38·1°.

r-*α-Hydroxy-β-glyoxaline*-4(or 5)-*propionic Acid*,



This acid results from the action of silver hydroxide on a hot aqueous solution of *r-α*-chloro-*β*-glyoxaline-4(or 5)-propionic acid. After the removal of silver chloride, the solution is treated with hydrogen sulphide, filtered from silver sulphide, and concentrated, when the hydroxy-acid crystallises out.

r-α-Hydroxy-β-glyoxaline-4(or 5)-*propionic acid* crystallises from water in prisms, which, after drying at 100°, melt at 222° (corr.). It contains one molecule of water of crystallisation, which is not lost at 100°, and is sparingly soluble in cold water or alcohol, but readily so in hot water:

0·1516 * gave 0·2290 CO_2 and 0·0776 H_2O. C = 41·2; H = 5·7.
0·1007 * „ 14·0 c.c. N_2 at 16° and 755 mm. N = 16·3.
$C_6H_8O_3N_2,H_2O$ requires C = 41·4; H = 5·8; N = 16·1 per cent.

Oxydeaminohistidine, the α-hydroxy-β-glyoxaline-4(or 5)-propionic acid obtained by the action of silver nitrite on *l*-histidine hydrochloride, also crystallises with $1H_2O$. It melts at 204° (Fränkel, *Monatsh.*, 1903, **24**, 229), and is, of course, the optically active variety corresponding with *l*-histidine.

4(or 5)-*Glyoxalinemethylchloromalonamide*, $C_3H_3N_2\cdot CH_2\cdot CCl(CO\cdot NH_2)_2$.

One gram of ethyl 4(or 5)-glyoxalinemethylchloromalonate hydrochloride was dissolved in a mixture of 20 c.c. of concentrated ammonia and 10 c.c. of alcohol, and the clear solution kept overnight. It was then evaporated to dryness under diminished pressure, the residue extracted with absolute alcohol, and filtered to remove ammonium chloride, these operations being repeated two or three times. The final alcoholic residue occurred as a varnish, which gave, with absolute alcoholic hydrogen chloride, 0·7 gram of 4(or 5)-*glyoxalinemethylchloromalonamide hydrochloride* as a crystalline precipitate. This salt was dissolved in a little water and mixed with absolute alcoholic hydrogen chloride, and on keeping separated in very pale buff, long, clear spikes, which darkened at 240° and decomposed at 245° (corr.).

It is anhydrous, readily soluble in water, but sparingly so in alcohol:

0·1500 gave 0·1821 CO_2 and 0·0567 H_2O. C = 33·1; H = 4·2.
0·0805 „ 14·8 c.c. N_2 at 18° and 766 mm. N = 21·7.
0·1858 „ 0·2100 AgCl. Cl = 27·9.
$C_7H_9O_2N_4Cl,HCl$ requires C = 33·2; H = 4·0; N = 22·1; Cl = 28·0 per cent.

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* Dried at 100°.

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